CHAPTER 6

FLOOD DAMAGES AND FLOOD DAMAGES PREVENTED

In spite of the dedicated efforts of everyone who responded to the flood emergency, all damages could not be prevented. Urban and rural areas alike incurred damages from uncontrolled runoff and releases from projects which had exceeded their flood control capacity. Had it not been for the flood control dams, however, warning time would have been decreased and the depth of flood water would have been much greater. Because of controlled releases and the efforts of hundreds of public and private volunteers, many of whom worked around the clock, the threat to life and property was significantly reduced.

FLOOD DAMAGES

The Tulsa District assessed flood damages in 19 cities and 49 counties in Oklahoma; 16 cities and 14 counties in Kansas; and 35 flood control projects. Flood damage information was obtained from various sources: information-gathering consultant firms; field surveys; state and local officials; the Federal Emergency Management Agency; the American Red Cross; and other agencies involved in disaster assistance.

Table 6-1 presents flood damage assessment values for urban areas; roads, bridges, and rural structures; and crops. In some cases, county totals are broken down into damage totals for particular cities.

Areas in Oklahoma with the greatest dollar amount of damage were: Washington County (Bartlesville), $37.2 million; Sand Springs, $32.5 million; and Bixby, $13.4 million.

TABLE 6-1

FLOOD DAMAGE ASSESSMENT
(Damages in $1,000's)

State County/City*	County Area (square miles)	Damages			
		Urban	Road, Bridges, and Rural Structures	Crops	Total
OKLAHOMA					
Adair	577	-	503.0	50.0	553.0
Alfalfa	864	-	350.0	2,086.0	2,436.0
Beckham	904	-	200.0	880.0	1,080.0
Blaine	920	-	226.0	3,361.0	3,587.0
Caddo	1,286	-	541.0	1,000.0	1,541.0
Canadian	901	-	203.0	3,940.0	4,143.0
Cherokee (Tahlequah)	748	450.0	169.0	170.0	789.0
Cleveland (Norman)	529	540.0	18.0	125.0	683.0
Craig	763	-	10.0	4,744.0	4,754.0
Creek	930	-	208.0	655.0	863.0
Custer	981	-	282.0	4,168.0	4,450.0
Delaware	720	-	15.0	1,071.0	1,086.0
Dewey (Oakwood)	1,007	142.0	498.0	1,560.0	2,200.0
Garfield	1,060	-	672.0	4,684.0	5,356.0
Grady	1,106	-	187.0	1,100.0	1,287.0
Grant	1,004	-	271.0	2,162.0	2,433.0
Greer	638	-	786.0	2,600.0	3,386.0
Harmon (Hollis)	537	250.0	-	500.0	750.0
Hughes	806	-	-	50.0	50.0
Jackson (Altus)	817	175.0	-	3,000.0	3,175.0
Kay	921	-	1,081.0	7,400.0	10,291.0
Ponca City		250.0	-	-	-
Tonkawa		60.0	-	-	-
Blackwell		1,500.0	-	-	-
Kingfisher (Kingfisher)	906	1,300.0	2,655.0	6,571.0	10,526.0
Kiowa	1,019	-	179.0	7,938.0	8,117.0
Lincoln	964	-	-	300.0	300.0
Logan	748	-	474.0	5,898.0	6,372.0
McClain	582	-	78.0	575.0	653.0
McIntosh	599	-	-	50.0	50.0
Major	958	-	194.0	510.0	704.0
Mayes (Salina)	644	50.0	-	525.0	575.0
Muskogee	815	-	747.0	3,000.0	3,747.0
Noble	736	-	290.0	4,815.0	5,105.0
Nowata (Nowata)	540	100.0	574.0	824.0	1,498.0
Okfuskee	628	-	138.0	130.0	268.0
Oklahoma	708	-	82.0	203.0	285.0
Okmulgee	698	-	272.0	1,499.0	1,771.0
Osage (Skiatook)	2,265	500.0	377.0	550.0	1,427.0
Ottawa (Miami)	465	11,616.0	266.0	1,487.0	13,369.0
Pawnee (Pawnee)	551	100.0	328.0	847.0	1,275.0
Payne (Stillwater)	691	120.0	678.0	4,785.0	5,583.0
Pottawatomie	783	-	-	3,849.0	3,849.0

TABLE 6-1 (Continued)

State County/City*	County Area (square miles)	Damages Urban	Road, Bridges, and Rural Structures	Crops	Total
Roger Mills	1,146	-	195.0	50.0	245.0
Rogers	683	-	33.0	640.0	673.0
Seminole	639	-	-	345.0	345.0
Sequoyah	678	-	227.0	970.0	1,197.0
Tillman	901	40.0	200.0	3,500.0	3,740.0
Tulsa	572	-	7,555.0	3,434.0	63,559.0
Bixby		13,399.0			
Sand Springs		32,496.0			
Tulsa		6,675.0			
Wagoner	559	-	367.0	2,667.0	3,034.0
Washington (Bartlesville)	423	37,238.0	668.0	1,828.0	39,730.0
Washita	1,006	-	748.0	1,700.0	2,448.0
KANSAS					
Allen					
Humbolt	505	-	1,466.0	1,909.0	3,375.0
Lola					
Bourbon	300	-	3,850.0	2,730.0	6,580.0
Butler	1,443	-	145.0	176.0	321.0
Chautauqua	644	-	2,792.0	600.0	3,392.0
Elgin	-	200.0	3.0	-	203.0
Peru	-	54.0	1.0	-	55.0
Niotaze	-	87.0	1.0	-	88.0
Sedan	-	136.0	2.0	-	138.0
Cedarvale	-	20.0	-	-	20.0
Cherokee	590	-	1,002.0	3,500.0	4,502.0
Baxter Springs	-	63.0	1.0	-	64.0
Cowley	1,128	-	360.0	375.0	735.0
Crawford	595	-	1,535.0	4,200.0	5,735.0
Elk	650	-	120.0	687.0	807.0
Greenwood	1,135	-	890.0	590.0	1,480.0
Labette	653	-	1,235.0	1,900.0	3,135.0
Parsons	-	200.0	3.0	-	203.0
Oswego	-	60.0	1.0	-	61.0
Montgomery	646	-	672.0	2,300.0	2,972.0
Independence	-	445.0	7.0	-	452.0
Coffeyville	-	100.0	2.0	-	102.0
Neosho	576	-	1,221.0	3,013.0	4,234.0
Chanute	-	70.0	1.0	-	71.0
Erie	-	100.0	2.0	-	102.0
Wilson	575	-	1,310.0	3,200.0	4,510.0
Altoona	-	210.0	3.0	-	213.0
Fredonia	-	70.0	1.0	-	71.0
Neodesha	-	1,020.0	15.0	-	1,035.0
Woodson	498	-	1,075.0	1,500.0	2,575.0

* = Table shows flood damages to counties and selected cities within counties. A city is shown parenthetically when only one is listed in that county.

Total flood damages from the storm event amounted to approximately $283 million. Tables 6-2 through 6-5 are summary sheets presenting the actual flood damage values for four reaches in the area. The reaches are as follows:

- From Hulah and Copan damsites on the Caney River to the Verdigris River.
- From Keystone dam to Snake Creek on the Arkansas River.
- From Snake Creek to the Oklahoma-Arkansas state line.
- At Miami, Oklahoma, on the Grand (Neosho) River.

These reaches account for about 55 percent of the total actual flood damages experienced in the 49 counties in Oklahoma and 14 counties in Kansas.

FLOOD DAMAGES PREVENTED

Tables 6-2 through 6-5 also present estimates of damage that would have occurred without the Arkansas River Basin flood control projects (uncontrolled damages) for the four reaches listed above.

Through the use of computer models and a data base of property values in the Arkansas River Basin flood plain, the Tulsa District determined the amount of damages which were prevented by the flood control projects. Table 6-6 shows these damage prevented values.

Total damages prevented by flood control projects amount to approximately $725 million. The flood control system also prevented additional loss of life. There were two lives lost in uncontrolled flooding areas. However, during a similar event, the 1943 flood, there were 26 lives lost with no flood control structures in place.

TABLE 6-2

SUMMARY OF ACTUAL AND UNCONTROLLED FLOOD DAMAGES
FROM HULAH AND COPAN DAM SITES ON THE CANEY RIVER
TO THE VERDIGRIS RIVER
(Damages in Dollars)

Properties	Actual Damages		Uncontrolled Damages	
	Units	Damages	Units	Damages
Single Family Residential and Contents	1,462	$39,566,000	3,237	$135,523,000
Multiple Family Residential and Contents	18	312,000	39	1,053,000
Mobile Homes and Contents	60	441,000	153	1,189,000
Commercial and Contents	38	4,880,000	41	5,741,000
Industrial and Contents	28	3,170,000	29	6,237,000
Streets and Roadways (city/town)		56,000		66,000
Highways and Bridges		9,742,000		12,898,000
Agricultural		5,209,000		8,825,000
Public and Quasi-Public Property (schools/parks)		661,000		778,000
Utilities (lines, poles, and property)		1,091,000		1,471,000
Total Damages		$65,128,000		$173,781,000

TABLE 6-3

SUMMARY OF ACTUAL AND UNCONTROLLED FLOOD DAMAGES
FROM KEYSTONE DAM TO SNAKE CREEK ON THE ARKANSAS RIVER
(Damages in Dollars)

Properties	Actual Damages		Uncontrolled Damages	
	Units	Damages	Units	Damages
Single Family Residential and Contents	1,170	$39,000,000	7,719	$346,000,000
Multiple Family Residential and Contents	139	960,000	5,124	67,000,000
Mobile Homes and Contents	444	5,000,000	882	10,000,000
Commercial and Contents	79	3,393,000	350	69,000,000
Industrial and Contents	4	1,600,000	180	82,000,000
Streets and Roadways (city/town)	19	227,000	126	2,000,000
Highways and Bridges	5	50,000	37	1,000,000
Agricultural		3,434,000		7,000,000
Public and Quasi-Public Property (schools/parks)	13	1,435,000	41	19,000,000
Utilities (lines, poles, and property)		933,000		9,000,000
Total Damages		$56,032,000		$612,000,000

APPENDIX B

AERIAL PHOTOGRAPHS OF

FLOOD AREAS AND FLOOD PROFILES

(Bound Separately)

TABLE 6-4

SUMMARY OF ACTUAL AND UNCONTROLLED FLOOD DAMAGES
FROM SNAKE CREEK TO THE OKLAHOMA - ARKANSAS STATE LINE ON THE ARKANSAS RIVER
(Damages in Dollars)

Properties	Actual Damages		Uncontrolled Damages	
	Units	Damages	Units	Damages
Single Family Residential and Contents	90	$2,056,000	562	$13,641,000
Multiple Family Residential and Contents	0	0	56	1,256,000
Mobile Homes and Contents	65	478,000	264	2,340,000
Commercial and Contents	9	165,000	83	4,726,000
Industrial and Contents *	60	1,698,000	288	10,787,000
Streets and Roadways (city/town)		374,000		567,000
Highways and Bridges		1,000,000		2,000,000
Agricultural		18,219,000		33,595,000
Public and Quasi-Public Property (schools/parks)	13	3,125,000	25	5,459,000
Utilities (lines, poles, and property)		207,000		993,000
Total Damages		$27,322,000		$75,354,000

* Includes 278 oil wells.

TABLE 6-5

SUMMARY OF ACTUAL AND UNCONTROLLED FLOOD DAMAGES
AT MIAMI, OKLAHOMA, ON THE NEOSHO RIVER
(Damages in Dollars)

Properties	Actual Damages		Uncontrolled Damages	
	Units	Damages	Units	Damages
Single Family Residential and Contents	208	$4,378,000	393	$9,700,000
Mobile Homes and Contents	26	116,000	32	207,000
Commercial and Contents	48	4,224,000	66	7,688,000
Industrial and Contents				
Streets and Roadways (city/town)		53,000		138,000
Highways and Bridges		138,000		150,000
Agricultural				
Public and Quasi-Public Property (schools/parks)	30	2,626,000	34	3,626,000
Utilities (lines, poles, and property)		50,000		106,000
Total Damages		$11,585,000		$21,615,000

TABLE 6-6

SUMMARY OF DAMAGES PREVENTED BY FLOOD CONTROL PROJECTS
(Damages Prevented in Dollars)

Subbasin/Project	Damages Prevented
Arkansas River Mainstem	
Canton	$210,000
Cheney	5,708,000
El Dorado	11,941,000
Eufaula	413,000
Fort Supply	5,000
Great Salt Plains	11,519,000
Heyburn	198,000
Kaw	198,113,000
Keystone	213,306,000
Thunderbird	560,000
Tulsa-West Tulsa Levee	135,144,000
Cimarron River Basin	
Keystone (also a mainstem lake)	see above
Grand (Neosho) River Basin	
Council Grove	240,000
Fort Gibson	6,619,000
Grand	4,354,000
Hudson	1,674,000
Iola Levee (Kansas)	1,320,000
Marion	40,000
John Redmond	3,014,000
Illinois River Basin	
Tenkiller	241,000
Verdigris River Basin	
Birch	145,000
Copan	47,428,000
Elk City	1,865,000
Fall River	1,340,000
Hulah	63,705,000
Oologah	12,436,000
Pearson-Skubitz Big Hill	298,000
Skiatook	1,769,000
Toronto	1,240,000
Total	$724,845,000 *

* - Includes $34.4 million damages prevented in the State of Arkansas by Tulsa District projects.

CHAPTER 7

ISSUES AND ACTIONS

Several questions and concerns were raised during and following the flood. Many of these have been addressed through responses to Congressional inquiries, letters, and meetings with concerned parties. **Table 7-1** lists and summarizes these issues. This chapter provides further discussion of some of these issues and details many of the ongoing efforts of the Tulsa District to improve flood control operations.

COMMUNICATIONS

Issue: One of the major problems encountered during the flood operations was in the area of communications. The Tulsa District offices were deluged with telephone calls from public officials, the news media, and the general public requesting information. Every effort was made to be responsive and provide the best, most up-to-date information available; however, there was considerable criticism that conflicting, faulty, unclear, and untimely information was received. Delineation of responsibilities of the Corps and/or other agencies for providing information, issuance of warnings, and notification to affected areas was unclear.

Action: The Tulsa District has established a Public Information Center (PIC), to be activated during emergency operations, to respond to requests for information. A diagram of the PIC is shown at **Figure 7-1**. Dedicated communication telephone lines have been installed to meet these needs. The Public Affairs Office will coordinate activities of the PIC so queries are handled as quickly as possible. The Public Affairs Office will also continue

TABLE 7-1

STATUS OF AFTER ACTION ISSUES
SEPTEMBER-OCTOBER 1986 FLOOD

Page	Description Action Item/Issue	Comments	Status
7-1	Perceived Communications Breakdown With Public Officials, News Media, and General Public	Completed	A public information center (PIC) has been established. PIC was activated during May 1987 flood.
7-5	Forecasting Procedures	Ongoing	Enhanced RADAR is scheduled for Oklahoma area in fiscal year 1988. New work group proposed to be established for making forecast in fiscal year 1988.
7-6	Access and Damages to Stream Gages	Ongoing	Funds of $250,000 available this fiscal year. Scheduled for completion in fiscal year 1988.
7-8	Electric Service and Personnel Access at Keystone Dam	Ongoing	Evaluation to be completed October 1987.
7-9	Availability of Flood Fighting Materials(Pumps, Riprap, Sandbags)	Ongoing	Pumps now available; riprap and sandbag evaluation and relocation to be completed in fiscal year 1988.
7-9	Keystone Traffic Control	Complete	During severe flooding, highway crossing dam will be closed.
7-10	Kaw Dam Control Room Flooding and Tailwater Staff Gage Too Low	Ongoing	Control room flooding alternatives to be completed in October 1987. Higher tailwater staff gage has been installed.
7-10	Induced Surcharge Limits	Complete	Evaluation has been made.

TABLE 7-1 (Continued)

Page	Description Action Item/Issue	Comments	Status
7-10	Power Sources at Projects	Ongoing	Evaluation scheduled for completion in October 1987.
7-11	Gate Operating Equipment Accessibility	Ongoing	Evaluation scheduled for completion in October 1987.
7-11	Keystone Powerhouse Stability During High Water	Ongoing	Evaluation scheduled for completion in October 1987.
7-11	Satellite Data Collection Backup	Ongoing	Installation completed at three gages. Evaluation to be completed in fiscal year 1988.
7-12	Interim Flood Area Maps	Ongoing	Maps will be completed in October 1988.
7-12	Flood Control-Bank Protection Measures for Bartlesville	Ongoing	Study scheduled for completion in July 1988.
7-13	System Operation Plan	Ongoing	Completion scheduled in July 1990.
7-14	Purchase of Land Below Oologah Spillway	Ongoing	Studies are complete recommending purchase of lands. Tulsa District is seeking authority to proceed with acquisition.
7-14	Backup for Water Control Computer	Ongoing	Scheduled for completion in fiscal year 1988.
7-14	Review of Reservoir Regulation Plans for Keystone, Hulah, and Copan	Ongoing	Study scheduled for completion in July 1990.

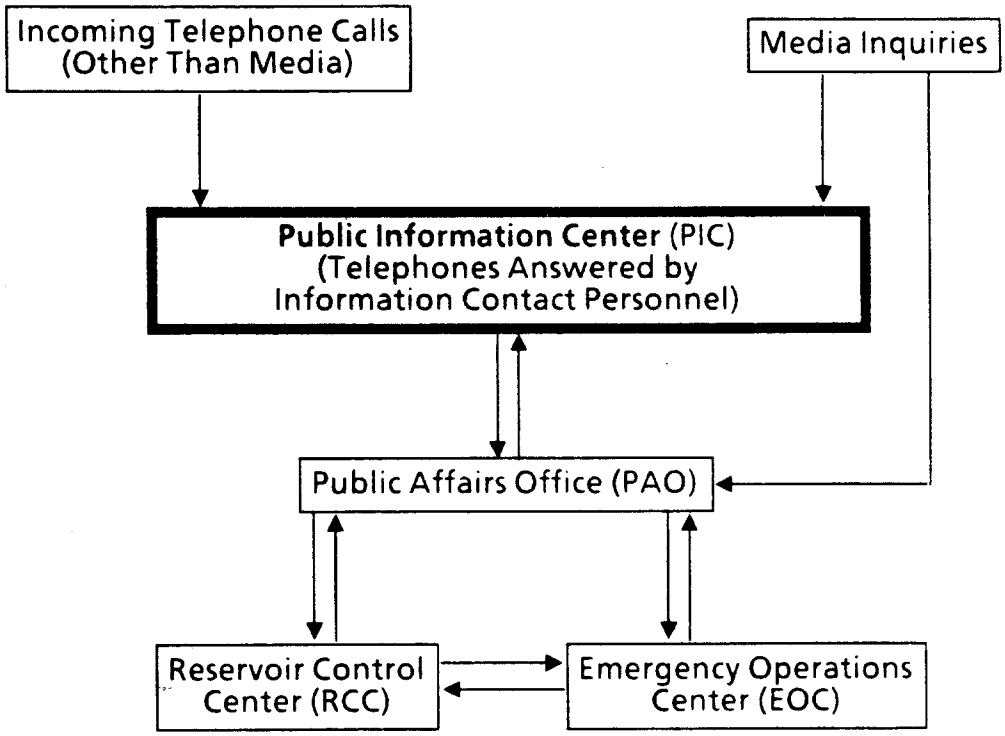

Figure 7-1 **Emergency Flood Operations**
Public Information Procedure

to coordinate with technical subject experts as needed for briefing material and regularly schedule media conferences. Telephone numbers into the Reservoir Control Section have been changed to provide more dedicated telephone capability to vital flood fighting operations. The PIC was activated for the first time during flooding that occurred in late May, 1987. Reaction from the public and other involved agencies was favorable, concluding that communications and availability had been considerably improved.

Personnel working in the Corps Emergency Operations Center (EOC) will continue to provide liaison with state and local civil defense, FEMA, and others involved in flood operations. An interagency group, with the purpose of developing a working agreement to clearly define respective responsibilities, has been formed, including all involved local, state, and Federal agencies.

FORECASTING

Issue: Considerable discussion has centered around forecasting procedures and capabilities required to predict lake inflows. Questions have also been raised concerning the use of radar information to enhance or supplement rainfall data required for forecasting.

Action: A review of all reservoir forecasting procedures has been conducted. This review included methodology of basic data gathering, automated application of climatological data, dependability of watershed runoff models, coordination with other elements, and organizational structure required to support forecasting efforts. As a result of this review, additional personnel will be assigned to improvement of watershed models and reservoir control. A

new work unit will be formed with a primary mission of improving and maintaining forecasting models and providing increased forecasting support during flood events.

The use of radar may be a significant enhancement for determining spatial distribution of rainfall when correlated to ground truth observance. Radar, to date, cannot be relied upon for rainfall totals. The Corps receives digital radar data from the Oklahoma City National Weather Services (OKC-NWS). An agreement exists between the Corps and OKC-NWS to supply the Tulsa District access to the RADAP II facility until such time as the NEXRAD (Next Generation Radar) system becomes functional. Oklahoma City is to receive the first NEXRAD installation within 25 months of the final test, which is scheduled for the spring of 1988. NEXRAD is viewed as a possible, significant improvement in obtaining rainfall information through radar. The Tulsa District has initiated correspondence with higher authority in an effort to secure dedicated communication ports to NEXRAD.

STREAM GAGES

Issue: Stream gages are located on bridges or on banks near streams. Gages are susceptible to damage by floating debris, erosion, lightning, and vandalism. These conditions are worsened during major floods. Flooding, particularly of roads, makes accessibility of gages for repair or measurement extremely difficult and dangerous. These problems were evident during the September-October 1986 flood.

Action: Several meetings have been held with the Oklahoma and Kansas offices of the U.S. Geological Survey (USGS) to discuss possible improvements to the gaging system. The USGS investigated the possibility of installing a cableway for the measurement of high flows on the Cimarron River near the Perkins gage, south of Stillwater, Oklahoma. This was found not to be feasible because of the width of the river when in flood stage. A new gage will be located at a better site, 7 miles downstream from Perkins, near Ripley, Oklahoma.

A list of 21 stream gages, critical to the operation of reservoirs, has been compiled. The Corps and USGS will install permanent staff gages at these critical gage sites. These staff gages will be used to manually obtain river stage readings in the event automated gages on bridges are washed out or become inaccessible. Twelve automated gages will be moved off bridges and relocated to high locations, thereby improving their accessibility and reducing the possibility of loss during major floods.

Methods of improving streamflow measurements and discharge rating curves are being investigated. Mathematical models, based on surveyed cross sections, will be used to extend discharge rating curves for the critical stream gaging stations. A sonic ranger device, which uses sound waves to measure river stages, will be investigated for possible use at some locations.

Three new data collection platforms (DCP) were installed in the Tulsa District by the USGS in June 1987, bringing the total in the Tulsa District to 159. They are located on the Cimarron River near Guthrie, Oklahoma; on the Caney River near Elgin, Kansas; and on the Elk River near Elk Falls, Kansas.

Funds in the amount of $250,000 have been received to initiate these improvements this year. It is estimated that $600,000 will be needed in 1988 to complete the improvements presently proposed.

FLOOD CONTROL STRUCTURES

Record releases from the flood control structures and record high lake and river elevations caused several concerns at the projects. None was serious enough to impair project operation, or threaten life; however, action was required to eliminate any potential threat to continued effective operation of the projects.

Keystone Dam

Issue: A high level of water was experienced at the Keystone powerhouse. Large flood releases from Keystone Dam caused flooding of the main transformer supplying power to the dam, including power needed to operate the gates. The high water also limited employee access to the powerhouse and damaged some powerhouse equipment.

Action: Flooding of the main transformer is not a critical situation. Secondary power is available from the Public Service Company of Oklahoma (PSO). There is also a diesel-powered auxiliary generator located above the powerhouse in the dam structure capable of supplying sufficient power to operate the flood gates and emergency lighting. Electrical difficulties with the gates and lighting have been lessened by the replacement of a stub power line from PSO. The power line will be completely eliminated with the expected October 1987 installation of a large transformer at an approximate cost of $15,000. A direct current source of temporary power is also available from powerhouse batteries. Auxiliary power sources will continue to be used during severe flood conditions. The sealing of openings around conduits and doors has reduced the probability of water entering the powerhouse. A secondary

employee access way will be constructed along the top of the parking lot wall with steps leading to the walk. Equipment cabinets will be raised three feet above the maximum water level observed during the flood. The milestone date for completion of these actions is October 1987.

Issue: Sandbags and riprap used for emergency repairs were not readily accessible during high water. Pumps needed for removing water from the powerhouse were not available.

Action: All Tulsa District Area Engineers have been asked to evaluate stockpile locations to guarantee easy accessibility during high water conditions. These evaluations and subsequent relocations, where needed, will be conducted during fiscal year 1987-88. Storage areas for sandbags will also be evaluated. These areas must also be easily accessible as well as weather-proof. Approval for funds to construct a separate storage area required at Keystone Dam has been requested. Pumps are now available in the vicinity of the powerhouse. Regular maintenance and operation checks will be conducted on each piece of equipment.

Issue: Sightseeing was a major problem. Heavy congestion on Highway 151 crossing Keystone Dam impeded emergency vehicle movement.

Action: The highway will be closed to public traffic during severe flooding. Temporary barricades will be placed at different locations around the lake as needed.

Kaw Dam

Issue: High water occurred at Kaw Dam. The control room and access stairways to the tainter gates narrowly avoided flooding when water reached the top of the surcharge pool. The spillway feeder circuit switchgear and standby generator are located in the control room; therefore, had flooding occurred, the tainter gates could have become inoperative. In addition, the tailwater staff gage was overtopped, making tailwater elevation readings impossible.

Action: Temporary measures have been taken to floodproof the structure. An architect/engineer firm has been hired to investigate alternatives to permanently correct these potential flooding problems. The study will be completed in October 1987. A higher tailwater staff gage has been installed.

The following items have also be identified by the Tulsa District for further analysis and possible action.

- Induced Surcharge Limits

A review of the induced surcharge operations used at several projects with gated spillways has been completed. This review identified the allowable safe induced surcharge for each project based on structural or operational limitations.

- Power Sources at Projects

Twenty projects in the Tulsa District have gated spillways. The adequacy of power sources during emergency operations at each of these projects is being evaluated. Considerations include location of power lines as well as

existing and backup power sources. This evaluation is scheduled to be completed in October 1987.

- Gate Operating Equipment Accessibility

Some dams have catwalks which do not provide safe access to gate operating equipment during induced surcharge operation. Studies are underway to determine appropriate corrections. These may include the installation of, or modification to, remote operating equipment and/or other structural modifications. The studies will be completed in October 1987.

- Keystone Powerhouse Stability During High Water

An analysis to determine powerhouse stability and the degree of protection that should be provided to it under high tailwater conditions is in process and scheduled for completion in October 1987. Flooding of the powerhouse would not affect operation of the spillway gates, but would affect power outputs from the dam and be expensive to repair.

A structural analysis of the powerhouse to determine its stability during exceptionally high releases will be completed in October 1987. Preliminary indications are that the structure must be allowed to flood when releases exceed 350,000 cfs. It must be emphasized, however, that the powerhouse concern has no effect on the safety of the dam.

- Satellite Data Collection Backup

For test purposes, telephone modems have been installed at three stations: Tulsa and Sperry, Oklahoma and Winfield, Kansas. These modems allow the District to interrogate data in the event access cannot be made by means of the satellite. An inventory of available telephone lines at key gages has been completed. This backup system is currently undergoing a

reliability evaluation. If these test sites are successful and it is determined that backups are required, then modems will be installed at other key gage sites.

- Interim Flooded Area Maps

The Tulsa District has requested funds for the preparation of interim, flooded area (below Keystone Lake) maps, covering a range of Keystone Dam flow releases. Maps will be completed in about a year after funds are received. They will outline the approximate flood area for Arkansas River flows ranging from 170,000 cfs to 480,000 cfs and will include the areas of Bixby, Broken Arrow, Jenks, Tulsa, and Sand Springs, Oklahoma. These maps could be used as guides by the respective communities to develop evacuation plans for various release rates.

The Tulsa District has recommended that an update of the Tulsa Flood Insurance Study be undertaken. This update should include surveys of the existing channel geometry and revised flood frequency studies, taking into account effects of the flood of September-October 1986. Flood frequency studies should include the effects future sedimentation in Kaw and Keystone Lakes will have on various frequency flood releases.

- Flood Control-Bank Protection Measures for Bartlesville

A reconnaissance study is currently underway which will address the flooding problems and potential solutions associated with the Caney River, including the reach through Bartlesville. It is scheduled for completion in May 1988. Two local protection reconnaissance studies specifically for Bartlesville have also been initiated.

Studies of the flood problem on Turkey Creek and flooding in the Kennilworth Addition are scheduled for completion in January 1988 and July 1988, respectively. These studies will define the existing flooding conditions, determine the feasibility of flood prevention measures, develop local cooperation requirements, and estimate construction costs of project development.

- System Operation Plan

The current Arkansas River Basin flood control system operating plan is under review in a joint feasibility study with the states of Oklahoma and Arkansas. The study is being accomplished in two phases. The first phase, expected to be completed in March 1988, is evaluating the taper portion of the plan used to transition from a flood control operation to a normal operation. The second phase will investigate possible changes to the system flood control operation and is scheduled for completion in July 1990.

A meeting of the Arkansas River Basin Coordinating Committee was held in Dallas, Texas on 28 January 1987. This committee is made up of various Federal, state, and local officials having an interest in the Arkansas River system operation. The purpose of this meeting was to discuss the system operating plan, past performance of the plan, and possible changes. The general consensus of the committee was that no changes should be made to the current operating plan until studies under way are completed and a need for change is warranted.

- Purchase of Land Below Oologah Spillway

Land below the spillway gates at Oologah Lake was damaged extensively during the flood. Flowage easements exist over these lands; however, studies are underway to determine the need to purchase additional land in this area. These studies are scheduled to be completed on October 30, 1987.

- Computer Backup System

A water control computer located at the U.S. Army Corps of Engineers, Southwestern Division (SWD) offices in Dallas, Texas will be used as a backup to the water control computer system in the Tulsa District. Steps are currently being taken to (1) make the SWD computer functionally equivalent to the Tulsa District computer, (2) install high speed communication capability between the SWD and Tulsa District water control computers, and (3) install necessary Tulsa District forecasting models and software on the SWD computer. Item 1 will be completed by October 1987, items 2 and 3 will be completed by January 1988.

In the event of a partial breakdown of the Tulsa District water control computer, the SWD computer would be accessible to maintain operations. In the event of complete loss of the Tulsa District computer, the SWD water control computer would still be accessible by using PC terminals.

- Review of Reservoir Regulation Plans for Keystone, Hulah and Copan

Subsequent to the September-October, 1986 flood the Tulsa District has reviewed the approved regulation plans for Keystone, Hulah and Copan.

The approved operating plans were followed during the September-October flood with the exception of the induced surcharge operation at Hulah Dam. The operation at Hulah utilized an additional 2.4 feet of surcharge storage. This operation prevented making large releases when the top of the designated surcharge pool was reached and prevented considerable downstream damages.

The current regulation plans state that no releases will be made if there is downstream flooding occurring or forecasted, unless the flood control storage is full or forecasted to fill. Following the September-October, 1986 flood there was some concern expressed that releases should be made earlier, based on forecasted rainfall, to keep the lakes at a lower level. Such an operation would not be desirable in most instances. Rainfall forecasts are very inaccurate for this area. The exact location, whether the rainfall is concentrated above or below the projects, and the amounts become critical and are unpredictable. Pre-releasing, based on forecasts, would in most cases result in additional damages downstream. For extremely large floods, which exceed the design flood control capability of the projects, the benefits of earlier releases would be minor because of the short time frame available to evacuate flood control storage. There is also concern about liability should releases be made early causing additional damages downstream and no further rainfall occurs or occurs downstream rather than upstream of the projects.

Current regulation plans appear appropriate at this time, however, a feasibility study currently underway for the Arkansas River Basin will investigate possible changes to the reservoir regulation plans.

CHAPTER 8

CONCLUSION

Vivid memories of the flood of September-October 1986 will remain for some time to come. It was an unprecedented, record-breaking event -- the worst flood ever experienced in several areas of northeastern Oklahoma.

The Arkansas River Basin flood control system was pressed to its limit during this flood. Because of physical and economic considerations during design, projects in the system have limited flood control capability. Various lakes fill their flood control storage on an average frequency of once every 10 to 30 years. During this event, 11 lakes equalled or exceeded their flood control capacities. In spite of the magnitude of this flood, the flood control system still provided significant benefits.

Damages resulting from the flood totaled about $283 million. Although damages were severe in some locations, it is estimated that the flood control projects prevented damages of about $725 million. More importantly, the controlled project releases provided advance warning time and undoubtedly saving many lives. The 1943 flood resulted in the loss of 26 lives. This flood exceeded the 1943 flood in most of the Arkansas River Basin, yet no lives were lost in areas downstream from Corps flood control lakes.

Lessons are to be learned from any experience. The flood of 1986 is no exception. The need for improvement in communications and coordination has been recognized. The Tulsa District has taken action to accomplish these improvements. The District intends to commit available resources to the

further enhancement of flood fighting operations so that they may continue to be conducted efficiently, within legal authorities, so that damages and human suffering are minimized.

This report should serve as an important management tool to promote better understanding, closer coordination, and improved cooperation for future flood fighting operations.

Questions pertaining to this document may be addressed to:

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